Using non-predictive theories to predict the nucleosynthesis of heavy elements.

Attempting an uncertainty evaluation...

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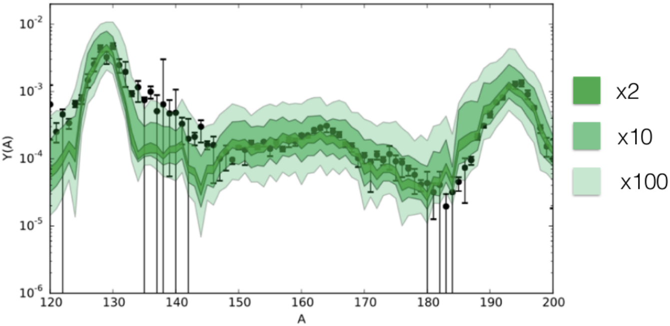
M. Mumpower, A. Falduto, A. Voinov.

Friday, March 10, 2017

R-PROCESS - IMPACT OF NEUTRON CAPTURE UNCERTAINTIES



Liddick et al. Phys. Rev. Lett. 116, 242502 (2016)

Mumpower et al., Prog. in Part. and Nucl. Phys. **86**, 86, (2016)

How could we estimate uncertainty?

- Statistical:
  Are the model parameters defined with enough precision? Are there correlations?
  Monte Carlo of parameters around a central value using some distribution,
  see e.g. Bertolli et al, arXiv:1310.4578 [astro-ph.SR]

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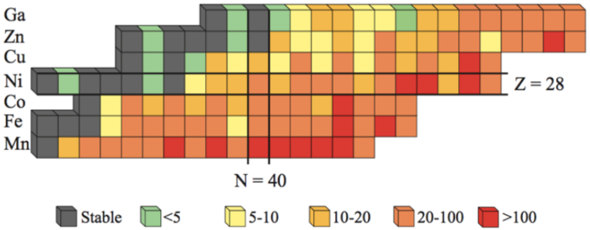
- Systematic:
  Is the model correct?
  Usual approach: Use various appropriate models and compare results.
  Problem: Perhaps the distribution is not well-sampled
  (e.g. Are all the models (equally) appropriate?)

"LET MANY FLOWERS BLOOM"

HOW MUCH UNCERTAINTY TO EXPECT?



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Nuclear Level Density	γ ray Strength Function
Constant Temperature matched to the Fermi Gas model (CT+BSFG)[11]	Kopecky-Uhl generalized Lorentzian (KU) [9]
Back-shifted Fermi Gas model (BSFG)[11],[12]	Hartree-Fock BCS + QRPA (HF-BCS+QRPA) [13]
Generalized Super fluid model (GSM)[14], [15]	Hartree-Fock-Bogolyubov + QRPA (HFB+QRPA) [16]
Hartree Fock using Skyrme force (HFS) [17]	Modified Lorentzian (Gor-ML)[18]
Hartree-Fock-Bogoliubov (Skyrme force) + combinatorial method (HFBS-C) [19]	

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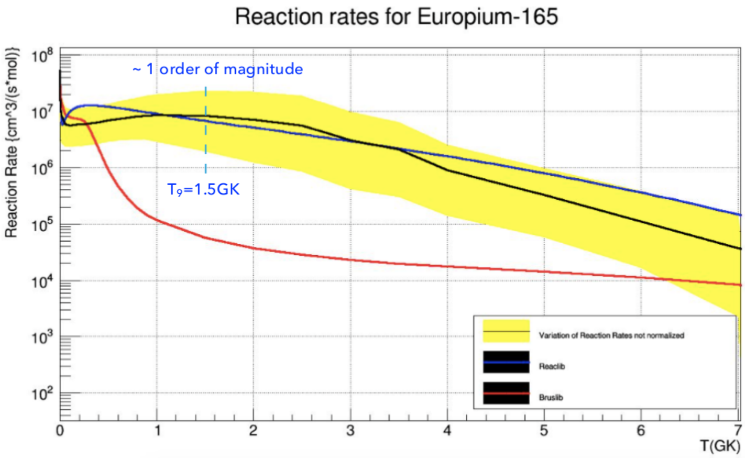
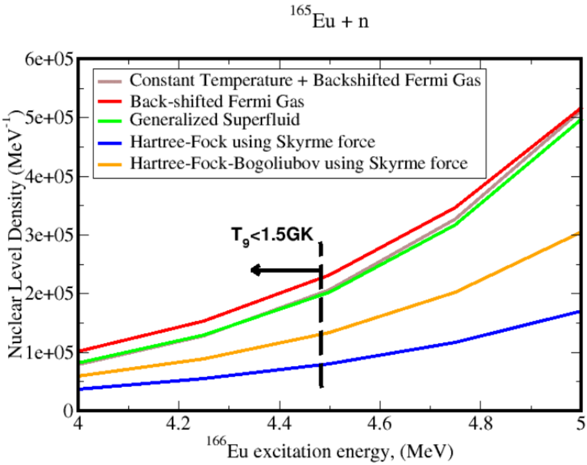
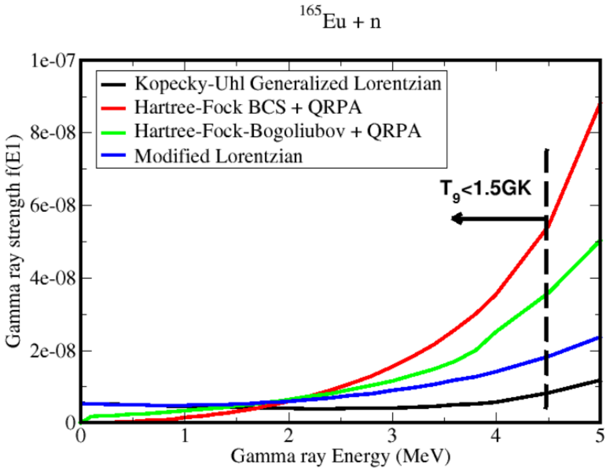


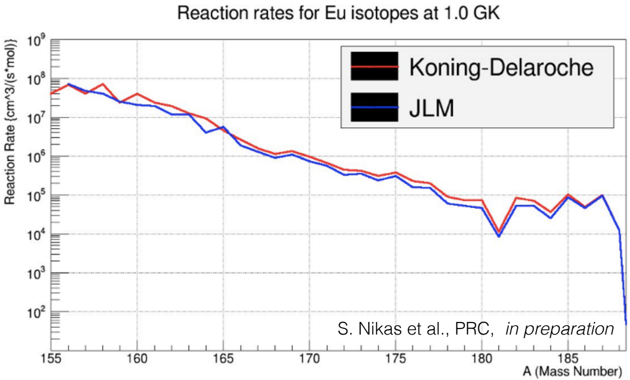
NUCLEAR LEVEL DENSITY



GAMMA RAY STRENGTH FUNCTION



What about the Optical Potential Uncertainty?



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The isovector imaginary neutron potential: A key ingredient for the r-process nucleosynthesis

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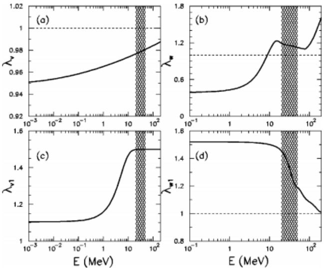
JLM semi-microscopic Optical Potential,



For n+ X(A,Z,N):

$$U(E) = \lambda_V(E)\left[V_0(E) + \lambda_{V_1}(E)\alpha V_1(E)\right]$$
$$+ i\lambda_W(E)\left[W_0(E) + \lambda_{W_1}(E)\alpha W_1(E)\right]$$

gray region: thorough checks with (p,p), (n,n) and (p,n) data, 1.5-10% uncertainty

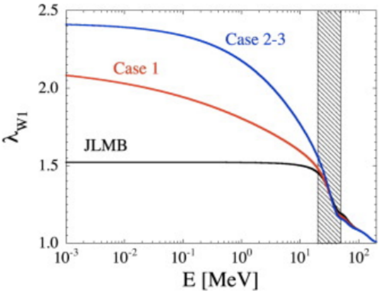
(Bauge, Delaroche, Girod, PRC63, (2001), 024607)

$$U(E) = \lambda_V(E)\left[V_0(E) + \lambda_{V_1}(E)\alpha V_1(E)\right] + i\lambda_W(E)\left[W_0(E) + \lambda_{W_1}(E)\alpha W_1(E)\right]$$

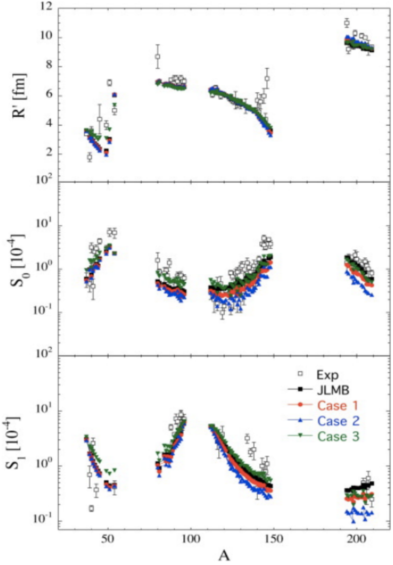
Case 1: 30% higher $\boldsymbol{\lambda_{w1}}$ @ 100keV

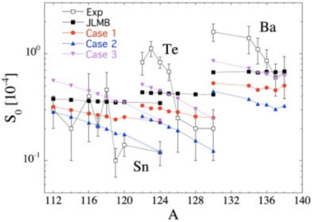
Case 2: 50% higher $\boldsymbol{\lambda_{w1}}$ @ 100keV

Case 3: 50% higher $\boldsymbol{\lambda_{w}}$ @ 100keV



(Goriely and Delaroche, PLB653, (2007), 178)





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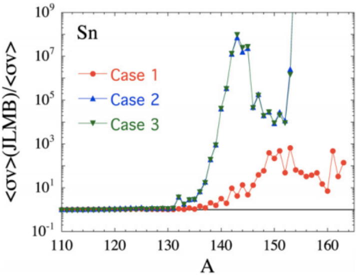
Is it important for astrophysics?



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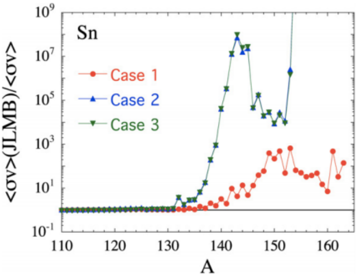
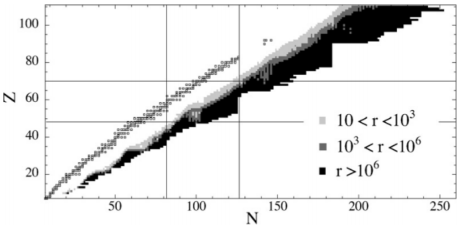
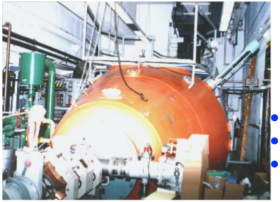


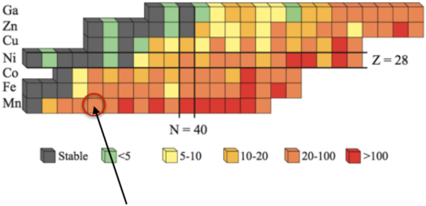
Yes, terrifying!





Proposed experiment @ Ohio U accelerator

- E_{beam} < 5MeV/u
- Experimental setup for particle evaporation measurements
- Region with experimentally constrained level densities



$^{11}B+^{48}Ca \rightarrow ^{59}Mn^*$ $\longrightarrow$ Measure evaporated particle yields

Conclusions-Wishlist

- Need microscopic theory to (at a minimum) understand trends in statistical properties of nuclei and eliminate models.
- A fully microscopic effective interaction useful for finite nuclei would be nice.
- Theoretical support is critical for experimental techniques applicable away from stability, e.g. beta-Oslo (measurements of level densities and γ ray stregths), Surrogate technique (indirect neutron cross section measurements).